The Influence of Anaerobic and Aerobic Fitness on the Technical Skill Ability of National Elite Male Under-18 African Soccer Players

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Abstract

Aim. Elite level soccer players cover about 10 km during a 90-minute game. Although running is the predominant activity in soccer, explosive movements such as sprinting, jumping and kicking are important for successful performance. The aims of this study were to determine the technical skill ability, aerobic- and anaerobic fitness of elite male under-18 African soccer players; and to determine whether a relationship exists between the technical skill ability and aerobic and anaerobic fitness. Methods. One-hundred-and-sixty-nine (n=169) elite male under-18 soccer players from eleven African countries participated in the study. Technical skill ability (dribbling, crossing, shooting, passing) was assessed using four soccer-specific tests. Aerobic and anaerobic fitness was measured through a 20-metre multi-stage shuttle run test and a repeated sprint ability test respectively. Results. The results showed that VO2max level (47.71 ml·kg-1·min-1) was much lower than indicated in literature (60 ml·kg-1·min-1). An average total distance of 704.36 m was recorded for the repeated sprint ability test. A positive correlation was found between dribbling and both aerobic and anaerobic fitness. Results indicated differences among various playing positions with forwards producing best performance in the passing and shooting skills test, forwards and defenders possessing the highest level of aerobic fitness and goalkeepers displaying the lowest level of aerobic and anaerobic fitness. Conclusion. Aerobic and anaerobic fitness influenced the players' ability to dribble. The African soccer players generally have a lower level of both aerobic and anaerobic fitness.

Keywords: *Soccer, technical skills, anaerobic fitness, VO_2max*

1. Introduction

Soccer is a team sport that requires the simultaneous performance of technical skills throughout high-intensity intermittent exercise.[1, 2] The ability to maintain technical performances (skills) throughout soccer match play is considered to be crucial in determining the outcome of competitive fixtures.[3] This is in line with a study by Mohr, Krustrup and Bangsbo [4], who indicated that fatigue had an influence on soccer performance towards the end of a match. In agreement with these studies, Rampinini *et al.* [5] and Russell, Benton and Kingsley [2] also reported a decline in several measures of technical skills during a match, especially a decline in the number of short passes completed and shooting skills due to match-related fatigue.

Elite-level soccer players cover a distance of approximately 10 km during a 90-minute game with an average intensity close to the anaerobic threshold (80-90 % of maximal heart rate).[6] Mean VO_2max of between 56-73.9 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ has been reported by Gil *et al.* [7] and Helgerud *et al.* [8] for elite youth soccer players. Soccer players with a higher level of aerobic fitness recover faster following acute bouts of maximal effort, tend to cover greater distances and perform more sprints during a game and can maintain their technical skills and mental concentration better towards the latter part of the game.[9] In line with this, Russell and Kingsley [3] claimed that strategies such as aerobic training have been found to improve proficiency in technical actions of soccer. It is therefore a prerequisite in the modern game for elite soccer players to have high aerobic endurance fitness.[10] For this reason, the routine monitoring of aerobic fitness in soccer players has been suggested. [6, 11-13]

Soccer involves many different types of activities from which the intensity can alternate at any time and range from standing still to maximal running.[14] An international top-class player performs approximately 1350 activities during a game, including about 220 runs at high speed.[4] According to Spencer *et al.* [15], the ability to perform repeated sprints with minimal recovery between sprint bouts forms an important aspect of team-sports. Establishing relationships between fitness measures and match performance is problematic due to the random pattern of activity, differences in exercise mode, sprint duration, number of sprint repetitions, type of recovery and varying influence of tactics during any given match.[15, 16] Prolonged protocols with structured and repetitive activity patterns have thus been developed. [17, 18]

Mechanisms that cause deterioration in skill during soccer-specific exercise remain to be fully elucidated and strategies to optimize technical performance throughout match-play warranted.[3] The primary aim of this study is to present normative physiological data on elite male under-18 African youth soccer players. The secondary aim is to determine whether a relationship exists between aerobic fitness and technical skill ability and between anaerobic fitness and technical skill ability.

2. Materials and Methods

The study made use of a quantitative research design and convenient sample. The sample (n = 169) consisted of elite, male under-18 African soccer players who were selected to represent eleven countries across the African continent in an Inter-Africa Tournament. Each country selected their players by means of their own selection process to represent their country in the tournament. Countries that participated in the tournament included South Africa, Nigeria, Uganda, Malawi, Zambia, Zimbabwe, Namibia, Botswana, Kenya, Tanzania and an ECABU (East and Central Africa Business Unit) Invitational Team. Ethical approval was obtained from the Ethics Committee of Tshwane University of Technology. An informed consent form was distributed to coaches before the tournament. Parental and player consent was obtained before players could participate in the study.

The Bleep test, as described by Ramsbottom, Brewer and Williams [19] was conducted to determine the aerobic fitness of each player. Anaerobic fitness was measured through a repeated sprint ability (RSA) test.[20] The technical skill tests (dribbling, crossing, shooting and passing) conducted was similar to that employed by Cook [21]. All the tests were conducted outdoors on a soccer field and the players warmed up before each test.

The purpose of the dribbling test was to determine how quickly and accurately the players could dribble a soccer ball through a set course and measured the players' ability to control the ball during dribbling. Two hundred (200) points were allocated for completing the course in 30 seconds, with ten (10) additional points added for every second finished under and ten (10) points deducted for every second finished over 30 seconds. The total score was divided by two-hundred-and-fifty (250) points to determine dribbling skill percentage (%).

The crossing test was used to determine the accuracy with which the players could kick a soccer ball through the air and hit a marked target. A scoring area consisting of three differently sized squares was measured on the soccer field using plastic tape and a line was marked 30 metres away from the middle square from where the players had to kick. Points were awarded for where the ball hit the ground for the first time. One-hundred (100) points were given if the ball hit the mannequin (in the middle square) without bouncing; fifty (50) points for landing in the middle square; forty (40) points for the second square and thirty (30) for landing in the third square. The total score was divided by three-hundred-and-fifty (350) to calculate crossing skill percentage (%).

The shooting test was used to determine the accuracy with which the players could kick a soccer ball towards a specific area in the goalpost and replicated goal scoring in a game. Players were awarded higher points for kicking the ball into the most difficult areas (top corners). Ten (10) points were awarded for hitting the bottom centre; twenty (20) points for the top centre; forty (40) points for the left or right bottom corners; and fifty (50) points for the left and right top corners. Shooting skill percentage (%) was determined by dividing the total score by two-hundred (200).

The passing test determined the accuracy with which the players could pass a soccer ball through designated gates. Four soccer balls were placed behind one another, 10 metres apart with two gates on the right hand side and two on the left (10 meters apart). Each player had to start at the designated marker (behind the first ball) and had four attempts at passing the balls through the gates. The player had to alternate feet when passing. Fifty (50) points were awarded for each successful pass through a gate and a bonus fifty (50) points if all four passes were successful and the player crossed the finishing line in 8 seconds. The total score were divided by two-hundred-and-fifty (250) points to determine passing skill percentage (%).

The data were analysed by a statistical package of social sciences, Statistica.[22] Descriptive statistics were used to report means, standard deviations and minimum- and maximum values. The Cronbach's Alpha score was used to establish the reliability of the technical skill ability tests. Spearman's Rank Correlation Coefficient was used to examine the strength of the relationship between variables (technical skill ability and the aerobic or anaerobic fitness). Analysis of variance (ANOVA) was applied to determine if there were differences among the player positions in all dependent variables. A Post-hoc Tuckey test was then conducted to determine which specific mean pairs (different player positions) differed significantly ($p<0.05$) from one another in terms of technical skill ability and aerobic and anaerobic fitness. The level of significance for all tests was set at $p<0.05$.

3. Results

3.1 Technical skill ability

As shown in Figure 1, the group as a whole scored an average of 62.6 % in the dribbling skill test, 57.9 % in the passing skill test, 36.2 % in the crossing skill test and 32.5 % in the shooting skill test. It thus seems as if the passing and dribbling skills are more developed than the crossing and shooting skills. It is furthermore evident from the minimum and maximum values that there is a wide range in terms of skill ability between individual players.

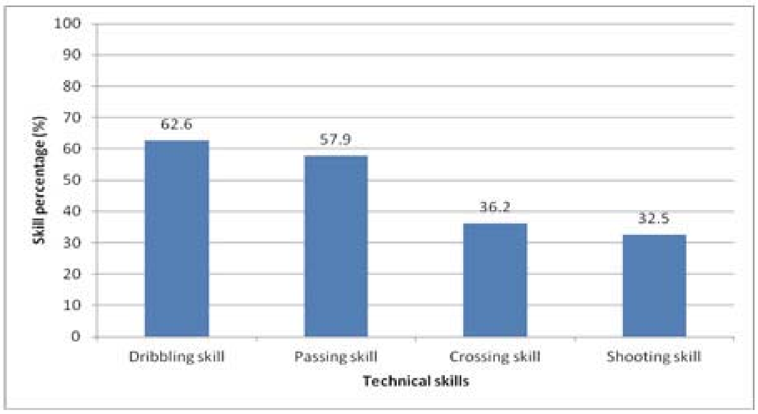

Figure 1: Performance scores for technical skill ability (n = 169)

3.2 Aerobic and anaerobic fitness

The average VO_2max for the group was 47.7 $ml \cdot kg^{-1} \cdot min^{-1}$ (Table I). In considering anaerobic performance through the repeated sprint shuttle test, an average total distance of 704.3 m and average shuttle distance of 118.4 m was recorded. An average fatigue index of 19.6 % was also recorded.

Table I: Descriptive statistics of the players' aerobic and anaerobic fitness (n = 169)

Variable	Mean ± SD	Minimum	Maximum
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	47.7±6.7	30.2	61.5
Rep Sprint total distance (m)	704.3±56.8	360	795
Rep Sprint average shuttle distance (m)	118.4±16.4	60	287.5
Rep Sprint Fatigue index (%)	19.6±16.9	3.8	100

3.3 Relationship between technical skill ability and aerobic and anaerobic fitness

A Spearman's Rank Order correlation was used to determine the relationship between the soccer players' technical skill level and aerobic and anaerobic fitness levels. Table II and Table III indicate that the dribbling skill was the only technical skill that correlated with fitness levels. No significant correlations were found between the other technical skills (passing, shooting and crossing) and the players' aerobic and anaerobic fitness.

There was a weak, positive correlation ($r=0.207$; $p<0.05$) between VO_2max scores and dribbling skill scores. This implies that higher levels of aerobic fitness are associated with higher dribbling scores and *vice versa*. This relationship was present at the 5 % level of significance.

Table II: Relationship between technical skill ability and aerobic fitness (n = 169)

Variable	Passing	Dribbling	Crossing	Shooting
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	r=0.038	r=0.207*	r=0.132	r=0.142

** p<0.05; Weak correlation: r≤ 0.2; Moderate correlation: r = 0.3 – 0.7; Strong correlation: r ≥ 0.8*

Table III: Relationship between technical skill ability and anaerobic fitness (n = 169)

Variable	Passing	Dribbling	Crossing	Shooting
Rep Sprint total distance (m)	r=-0.000	r=0.258*	r=-0.013	r=0.030
Rep Sprint average shuttle distance (m)	r=-0.069	r=0.192*	r=0.021	r=0.006
Rep Sprint Fatigue index (%)	r=-0.045	r=-0.052	r=0.037	r=-0.097

** p<0.05; Weak correlation: r≤ 0.2; Moderate correlation: r = 0.3 – 0.7; Strong correlation: r ≥ 0.8*

Dribbling skill scores also showed a weak, positive correlation with the repeated sprint total distance (r=0.258; p<0.05) and a very weak correlation with repeated sprint average shuttle distance (r=0.192; p<0.05). As dribbling scores increase, one can thus expect an increase in sprint total distance, as well as an increase in scores on sprint average shuttle distance, which implies higher levels of anaerobic fitness. Lower scores on dribbling will be associated with lower scores on sprint total distance and on sprint average shuttle distance. None of the technical skill scores correlated significantly with the sprint fatigue index.

4. Discussion

The results of the study indicate that the players performed overall the best in the dribbling (62.6 %) and passing (57.9 %) skill tests, and did not produce good performance in both the crossing (36.2 %) and shooting (32.5 %) skill tests. These results are in direct contrast with the crossing and shooting skill tests conducted by Vaeyens *et al.* [23], which were fairly similar to the tests conducted in the present study. Vaeyens *et al .*[23] found that elite, male under-16 soccer players (n=34) produced good performance in both the crossing (77 %) and shooting (79.3 %) skill tests. The difference might be due to different degrees of emphasis being placed on specific skills during training. Both crossing and shooting skills are important in achieving success in a soccer game in order to pass accurate passes to team members and shoot goals.

According to Malina *et al*. [24], age, years of experience in soccer, body size and maturity status contributed significantly to variation in performance on four soccer-specific technical skills tested. In the study of Malina *et al.* [24], biological maturity contributed to variation in ball control with the body and head, dribbling speed with a pass for accuracy, and shooting accuracy, suggesting that within that particular group, biological maturity status were associated with a slightly better performance in these tests. The maturity status of the players in the present study could also explain why some players performed much better than others in some of the technical skills tests, as it has been previously proven by Malina *et al.* [24] that better performance on certain skills test is associated with a more advanced biological maturity status. Maturity status is thus a factor which should be considered in future research on this particular population.

In considering different player position categories, the forwards performed the best in the passing skill test (59.32 %) followed by the defenders (58.57 %). The worst performance was measured amongst the goalkeepers (57.24 %) and midfielders (57.03 %). The forwards also produced the best performance in the shooting skill test (34 %), followed by midfielders (32.76 %) and then defenders (32.66 %). This is in line with results reported by Jordet *et al.* [25], on technical skills tests, who also found that forwards produced the best performance, followed by midfielders and defenders. Although the forwards produced the best performance in the passing and shooting skills tests, the results were not statistically significant compared to the other player positions.

It is of interest to note that the goalkeepers produced the best performance in the dribbling skill test (65.23 %) and the forwards the worst performance (60.75 %), as effective dribbling forms an important element of the positional demands of both forward and midfield players and is not such an important requirement for the goalkeeping position. The goalkeepers also produced the best performance in the crossing skill test (41.42 %) compared to the forwards (38.85 %), midfielders (34.28 %) and defenders (35.38 %). This result could be related back to their positional responsibilities when taking a free kick from the goal area and kicking the ball through the air with accuracy to a specific team player. The differences in the results for the different player positions were, however, also not statistically significant.

The aerobic system is critical for energy delivery in team sports.[26] Although the players tested in the current study are elite players, the average value calculated for aerobic fitness is quite low (VO_2max = 47.71 $ml·kg^{-1}·min^{-1}$) compared to some other studies.[8, 9] Even though a maximum value of 61.5 $ml·kg^{-1}·min^{-1}$ was recorded, another study by Helgerud *et al.* [8] found much higher VO_2max values (64.3 $ml·kg^{-1}·min^{-1}$, 73.9 $ml·kg^{-1}·min^{-1}$) in the same age groups. However, Aziz *et al.* [9] found, with a similar 20-metre multistage shuttle run test, estimated VO_2max values, over a three-year period, of 54.8 $ml·kg^{-1}·min^{-1}$ (2002), 56.8 $ml·kg^{-1}·min^{-1}$ (2003) and 57.6 $ml·kg^{-1}·min^{-1}$ (2004). The values recorded in the present study are also slightly lower than those reported by Gil *et al.* [7] for players of different age groups belonging to the Arenas Club de Getxo (Bizkaia, Spain), with VO_2max values of 56 $ml·kg^{-1}·min^{-1}$ (14 years), 58 $ml·kg^{-1}·min^{-1}$ (15 years), 53 $ml·kg^{-1}·min^{-1}$ (16 years) and 62 $ml·kg^{-1}·min^{-1}$ (17 years).

The values of the present study are below the previously suggested minimum VO_2max of 60 $ml·kg^{-1}·min^{-1}$ for top professional soccer players, however, this minimum value was reported for top professional senior players (mean age = 26.1 years).[27] Stølen *et al.* [6] recommended an even higher value of 70 $ml·kg^{-1}·min^{-1}$ to perform optimally at top-level. It should, however, be noted that the players in the present study were elite youth players and not top professional players, whose aerobic fitness levels might still improve with age and specific training regimes. It is thus evident through the results of the present study that the elite African youth players' VO_2max values are in relative close proximity to those reached by similarly aged players from other continents, but are much lower than that recommended to play at a top level.

When compared according to playing position, the goalkeepers obtained the lowest average VO_2max (45.21 $ml·kg^{-1}·min^{-1}$) followed by midfielders (47.52 $ml·kg^{-1}·min^{-1}$). These values did, however, not show any significant difference when compared to the defenders (48.53 $ml·kg^{-1}·min^{-1}$) and forwards (48.34 $ml·kg^{-1}·min^{-1}$). These results are in line with what was found in literature [7, 28], where the goalkeepers (48.41 $ml·kg^{-1}·min^{-1}$ and 55.7 $ml·kg^{-1}·min^{-1}$) also delivered the lowest VO_2max scores. Much higher values were, however, reported for the forwards (62.4 $ml·kg^{-1}·min^{-1}$ and 60 $ml·kg^{-1}·min^{-1}$), midfielders (57.71 $ml·kg^{-1}·min^{-1}$ and 60.4 $ml·kg^{-1}·min^{-1}$) and defenders (58.55 $ml·kg^{-1}·min^{-1}$ and 59.6 $ml·kg^{-1}·min^{-1}$). Gil *et al.* [7], however, pointed out that midfielders need the highest level of aerobic fitness, because they run the longest distances during a match due to their linking role between the back and centre of the field with the front. The results from literature indicate that the goalkeepers' aerobic fitness differed statistically significantly from the other players, with goalkeepers also displaying the lowest VO_2max value [7, 28] ,while the results of the goalkeepers in this study did not show such a large difference. The results of this study thus also indicate that the specific player positions of elite African youth soccer players reached lower average levels in aerobic fitness in comparison to other international elite youth soccer players. Through these results mentioned it is evident that goalkeepers tend to have the lowest aerobic fitness level in comparison to players in other positions. Even though goalkeepers have different demands and roles to perform during a game, it should not be used as an excuse to pay little attention to their aerobic fitness. Good aerobic fitness is necessary in order to endure long training sessions and games.[7]

Pearson, Naughton and Torode [29] mentioned that the greatest improvement in aerobic fitness occurs between the ages of 11 and 15 years, which could possibly explain why some of the players (within this age range) did not possess a high level of aerobic fitness. However, some of the players fall within or closely to these ranges suggested. The large difference between the maximum and minimum VO_2max values recorded, and the large difference between the VO_2max of players in this study compared to that of players in other international studies, might also be due to different training regimes.

RSA can be investigated using various different protocols.[15] It is, however, difficult to compare between studies because of the large difference in exercise mode, sprint duration, number of sprint repetitions, length of recovery, and the training status of the players. Activity while directly involved with the ball is largely anaerobic [28] which explain why high anaerobic fitness is an important factor for success in soccer. Sprinting ability over distances of 5 to 30 metres is vital in the physiological profile of soccer players [14], which is why the RSA test used in the current study can be seen as being applicable to game demands.

The average total distance achieved by the players in this study were considerably lower (704.36 m) than the average (734 m) reported by Durandt *et al.* [30] for South African soccer players (mean age= 24 years), although these players are younger than those in the study of Durandt *et al.* [30]. It is also clear through the minimum and maximum values of the total distance covered (360 m and 795 m), that large differences exist between players. An average shuttle distance of 118.44 m was recorded for the group, with minimum and maximum values of 60 m and 287.5 m respectively. This indicates a significant difference between the players in terms of anaerobic fitness. Spencer *et al.* [15] reported a substantial variation for estimated total sprint distance during a soccer game, ranging from 670-975 m for elite soccer players. Although the scientific literature is not abundant with studies investigating the physiology of RSA [15], it can be accepted that the RSA test used in the study is a reflection of the distance covered during a soccer game, which also requires the players to complete several sprints in a short duration of time.

The fatigue index percentage (%) indicated an average of 19.61 %. The minimum difference between the best and worst shuttle distance was only 3.84 %, indicating a small decline in performance in some instances. A maximum fatigue index of 100 % was also recorded, indicating a discontinuation of the test by some players, which might be due to insufficient anaerobic fitness or lack of motivation. It should be noted that a lower fatigue index score equals a higher level of anaerobic fitness and *vice versa*.

Significant differences ($p<0.05$) were detected between player positions with regards to total distance and average shuttle distance performed. The results indicate that the goalkeepers as a whole produced the worst performance in the RSA test. When considering the repeated sprint total distance recorded for goalkeepers (651.25 m) compared to that of defenders (711.81 m), midfielders (709 m) and forwards (711 m), it is evident that the goalkeepers did not possess the same level of anaerobic fitness. In a similar test conducted by Durandt *et al.* [30] on elite South African soccer players (mean age= 24), the forwards produced the best performance (748 m) followed by the midfielders (744 m) and defenders (714 m). No results were reported for goalkeepers. When comparing these two studies, the total African group produced a much lower performance than that of the South African players in the study by Durandt *et al.* [30] indicating a lower level of anaerobic fitness, which might be due to the age difference in the two studies respectively.

The best shuttle distance recorded was among the midfielders (131 m) and was closely followed by the defenders (130 m) and forwards (128.83 m). The highest recording for the midfielders can be related to the roles they need to fulfil in a game, as it has been reported by Gil *et al.* [7] that midfielders play a linking role between the back and centre of the field with the front. In considering the average shuttle distance performed, the forwards achieved the highest total (124.06 m), which also differed significantly from the goalkeepers (108.54 m). The midfielders and defenders produced fairly similar results (118.17 m and 118.63 m). The largest differences were detected between the goalkeepers and the other positions, which might be related to their positional roles requiring less or shorter sprints.

The results calculated for fatigue index (%) did not indicate a significant difference between the different player positions. The goalkeepers scored the worst average fatigue index (22.84 %), followed by the midfielders (20.29 %) and forwards (20.23 %). The defenders scored a fairly lower average fatigue index (17.17 %). These results indicate that the difference in distance covered between the best and worst shuttle performed were fairly close for the defenders which could indicate that their anaerobic ability might be better during a game because of a slower rate of getting fatigued.

These results show that all the players produced a much weaker performance in the test compared to those in the study by Durandt *et al.* [30], even though there were no large differences between the forwards, midfielders and defenders of the current study. The weak result of the goalkeepers' anaerobic fitness might be due to their positional responsibilities and training regimes, which might be different to that of other players. Although goalkeepers also perform short explosive sprints when defending the goalpost, the other players (forwards, midfielders and defenders) need to cover more and longer sprint distances during a game.[4, 31] This is in line with Bangsbo and Michalsik [32] who reported a sprinting distance of only 1-12 metres for goalkeepers. The positional demands of the game could explain why forwards, midfielders and defenders performed much better in the RSA test.[27] Thus, when interpreting the results of a RSA test, the training status and positional responsibilities of the players should also be considered.

Technical abilities are important determinants of soccer performance.[5] The only skill that correlated positively with aerobic fitness was the dribbling skill. No significant relationship was found between the other technical skills and aerobic fitness. The dribbling skill was also the only skill which correlated positively with anaerobic fitness. A conclusion might be drawn based on the fact that dribbling a soccer ball also requires aerobic or anaerobic fitness or a combination of these, depending on the situation in a game. A player might be required to dribble the ball for a long distance or while sprinting, while still maintaining control over the ball. The results could also be used to explain why there is no relationship between the other technical skills (shooting, passing and crossing) and both aerobic and anaerobic fitness. These skills could be performed while stationary or in motion, and it might thus not be required to have a better level of aerobic or anaerobic fitness in order to perform the skill better. Thus, while dribbling involves running or sprinting, the other skills are not dependent on these abilities in order to perform the skill.

While high physical fitness allows the player to remain involved with the play and perform more high-intensity activities, the overall performance in soccer games is usually determined by the technical skill ability of players.[8, 33, 34] Rampinini *et al.* [5] claimed that the ability to compete at high-intensity during a game as well as the ability to have greater involvements with the ball and complete more skill-related activities is important to be successful in professional soccer. Soccer performance at optimal levels requires high levels of technical, tactical, psychological and physiological skills.[35, 36] Thus, a conclusion could be drawn that the players with a higher level of aerobic and anaerobic fitness, would be more involved during the game, and if these players have a better technical skill ability, they might have a competitive advantage over the less skilled or less fit players.

5. Conclusions

There are many factors that predispose towards a successful career in professional soccer. There appears to be a decline in the exercise intensity, due to fatigue, of top-class soccer players during a game. The physical capacity of soccer players influences their technical performance. The present study evaluated the technical skill ability, aerobic and anaerobic fitness of the players and investigated the relationships between technical skills and the fitness parameters. A number of studies have evaluated technical skill ability and the aerobic and anaerobic fitness of elite youth soccer players using various different methods.[6, 7, 14] However, there is comparatively little information on African soccer players. Due to the large number of technical skills tests available, it is also difficult to compare results across different studies. The results of the study can be used to establish norms and compare the findings to other international studies. Further studies should be conducted to evaluate level of maturity and the influence of the period during the selection year in which the players were born. These studies should also include different levels of play, namely school, club and provincial teams. Considering all the advantages of a high level of physical capacity, more focus should thus be attended on how to effectively train the different physical capacities.

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